# PRECISION MEASUREMENT OF THE HIGGS BOSON MASS AND SEARCH FOR DILEPTON MASS RESONANCES IN H $\rightarrow 4\ell$ DECAYS USING THE CMS DETECTOR AT THE LHC

By

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This work is dedicated to the living and loving memory of Jacob Myhre.

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Co-Chair: Guenakh Mitselmakher
Major: Physics

The mass of the Higgs boson is measured in the $H \rightarrow ZZ^* \rightarrow 4\ell$ ($\ell = e, \mu$) decay channel and is found to be $m_H = 125.38 \pm 0.11\,\text{GeV}$; the most precise measurement of $m_H$ in the world to date. The data for the measurement were produced from proton-proton (pp) collisions at the Large Hadron Collider with a center-of-mass energy of 13 TeV during Run 2 (2016–2018), corresponding to an integrated luminosity of $137.1\,\text{fb}^{-1}$, and were collected by the Compact Muon Solenoid experiment. This measurement uses an improved analysis technique in which the final state muon tracks are constrained to originate from the primary pp vertex. Using data sets from the same run, a search for low-mass dilepton resonances in Higgs boson decays to the $4\ell$ final state is also conducted. No significant deviation from the Standard Model prediction is observed.

# CHAPTER 1
# SEARCH FOR LOW-MASS DILEPTON RESONANCES IN THE H $\to 4\ell$ CHANNEL

## 1.1 Motivation

As mentioned in Sec. **??**, even though the Higgs boson has been well studied and *appears* to be consistent with the SM Higgs boson, a single experiment that shows BSM activity (i.e., *any* deviation from SM prediction) is all that is required to completely defenestrate this idea. For example, it may be the case that the Higgs boson (H) decays into particles other than those found in the SM. This chapter details such an analysis, which follows similar topologies to the one studied in Chapter **??** ($H \to ZZ^* \to 4\ell$), specifically $H \to ZX \to 4\ell$ and $H \to XX \to 4\ell$, where X is a BSM low-mass dilepton resonance.

## 1.2 Data Sets, Simulated Samples, and Triggers

The data sets used for the search for low-mass dilepton mass resonances in SM Higgs boson decays uses the same data sets for all three years (2016–2018) as those found in Ref. **??**. A brief explanation of the parameters used to generate the data sets follows next.

The physics processes corresponding to the signal $pp \to H \to ZZ_D\,(Z_DZ_D) \to 4\ell$, where $\ell = (e, \mu)$, were generated at leading order (LO) using MadGraph5_aMC@NLO 2.2.2 (2.4.2) for 2016 (2017, 2018) samples using the parameters set by the HAHM. On the other hand, POWHEG v2 was used to simulate the production of SM Higgs bosons via the typical processes (ggH, VBF, VH, and $t\bar{t}H$) and to simulate $q\bar{q} \to ZZ$ at next-to-leading order (NLO) using perturbative quantum chromodynamics (Refs. [1–4]). The other irreducible background process ggZZ was simulated using MCFM 7.0.1 (Ref. [5]) at LO, to which NLO correction factors were applied (Ref. [6]). The simulation of $H \to 4\ell$ was carried out by the software JHUGen 7.0.2 (Ref. [7, 8]).

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## BIOGRAPHICAL SKETCH

Jake Rosenzweig had the best childhood anyone could ask for, growing up in Jacksonville, FL: enjoying video games with excellent friends, playing football on the beach, and having plenty of opportunity to make mistakes. He graduated from the University of Florida in 2011 with a B.S. in chemistry, while maintaining his sanity by getting minors in education and Latin. He enjoys building things from scrap, weightlifting, hiking in the Coloradoan mountains, gardening, silence, and—most of all—receiving the beleaguered stare from his wife after telling her a *particularly* bad dad joke.